App. Envi. Res. 43(2) (2021): 46-59

Supplementary Material (SM)

Inspection and Understanding of Sewer Network Condition in Dindaeng District (Thailand)

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SM 1 Various methods of inspection for underground pipeline

No.	Method	Advantage	Reference
1	Visual/Person-Entry Inspection	• Detection of pipe defects, such as structural defects (e.g., cracks, breaks, deformation), service defects (e.g., protruding laterals, grease build-up, obstructions) by trained individuals	[6]
2	Closed Circuit Television (CCTV)	• Effective inspection of sewer pipelines • Detection of sewer pipe defects • Determination of defect type, location of defects from video records	[6]
3	Sonar/CCTV	• Sonar: Detection of area below sewer flowline of inverted sewer pipelines (true shape of pipelines, detection of sedimentation) • CCTV: Detection of area above sewer flowline of crown sewer pipelines • Complete picture	[6]
4	Dye Testing	• Tracer method • Checking effluent flow by non-toxic powder dye	[7]
5	Zoom Camera Technology	• Detection for visual inspection • Truck-mounted camera equipment with long-range zoom lens, powerful halogen spotlights • Continuous image of interior surface of pipes	[7]
6	Sewer Scanners and Evaluation Technology (SSET)	• Non-destructive detection of sewer pipelines with multi-sensor • Providing multi-source data from scanning of pipelines • 360 degree rotation, scanning, recording • More effective than conventional CCTV because of high-resolution 2D images • Recording of all damage • Measurement of horizontal and vertical pipe deflections by gyroscope system	[7]
7	Ground Penetration Radar (GPR)	• Measuring strength, delay time of refraction waves • First application: To detect location, depth of underground sewer systems • Recent application: To evaluate quality of rehabilitation projects in slip lining, cure-in-place liners by specialized GPR units	[7]

SM 1 Various methods of inspection for underground pipeline (*continued*)

No.	Method	Advantage	Reference
8	Ultrasonic Inspection (Sonar)	• Detection of surface of objects of interest by high frequency sound waves • Detection of pipe-wall deflection, corrosion loss, cracks/pits in the cross-section of pipe walls, volume of debris in inverts	[7]
9	Impulse Hammer	• Detection of brick sewer by dynamic hammer which generates broadband frequency excitation of structures	[7]
10	Smoke Testing	• Quick, inexpensive method for detection of leaks, broken pipes, improper connections	[7]
11	Acoustic Sensors	• Detection of signals produced by defective points • Three types: • Leak detectors that detect acoustic signals produced by leaks in pipelines • Acoustic monitoring systems that detect signals produced by breaking of pre-stressed wires in pre-stressed concrete cylinder pipes (PCCP) • Sonar/ultrasonic systems that detect various pipe defects by high frequency sound waves	[8]
12	Electrical/ Electromagnetic	• Basis evaluation techniques for sewerage • Detection of leaks in surcharged non-ferrous pipes • Detection of ferrous pipes by eddy current testing (EDT), remote field eddy current (RFEC) technology	[8]
13	Laser Profiling	• Detection of pipeline shape • Laser for detection of pipe corrosion, deformation, siltation	[8]
14	Infrared Thermography	• Detection of sewer defects • Measurement of temperature variations on target surface for detection of leaks, voids while sufficient internal/external temperature exist	[8]
15	Flow Rate Measurement	• Conventional method for infiltration of sewerage • Simple, widely used	[9]
16	Stable Isotopes Method	• Measurement of different isotopic signatures from distant hydrological sources • Measurement of quantified infiltration from parasitic water (e.g., groundwater, local precipitation) in sewerage	[10]
17	Pollutant Time Series Method	• Analysis of time-series data of pollutant concentrations, sewer flows with high temporal resolutions • Estimation of infiltration by measurement of data (parameter set), pollutant concentrations by time	[11]

SM 2 Score system for structural condition [21]

No.	Code	Description	Condition rating score		
			S	M	L
1	CC	Crack Circumferential	2	15	30
2	CL	Crack Longitudinal	3	15	30
3	CM	Crack Multiple	10	20	40
4	DF	Deformed Pipe	Not used	25	65
5	DP	Dipped Pipe	10	15	35
6	IP	Infiltration at pipe wall	2	15	30
7	JD	Joint Displaced	0	15	45
8	JF	Joint Faulty	1	10	25
9	JO	Joint Open	0	5	25
10	LF	Lateral sealing defective	5	10	25
11	LP	Lateral Protruding	0	15	25
12	LX	Lateral Problem	5	20	30
13	OP	Obstruction Permanent	10	20	35
14	PB	Pipe Broken	15	30	75
15	PF	Deformed Plastic Pipe	5	10	30
16	PH	Pipe Holed	5	25	40
17	PL	Protective Lining Defective	5	25	60
18	PX	Pipe Collapsed	N/A	N/A	100
19	SD	Surface Damage	3	20	60
20	TM	Tomo	N/A	N/A	40

SM 3 Grading system for structural condition [21]

Grading	Peak score		Mean score	
	Initial	Intermediate	Initial	Intermediate
1.0 Excellent	0 – 2.0	0 – 2.0	0 – 0.5	0 – 0.5
2.0 Good	2.1 – 15.0	2.1 – 15.0	0.51 – 0.9.0	0.51 – 0.9.0
3.0 Moderate		15.1 – 20.0		0.91 – 1.18
3.4	15.1 – 30.0	20.1 – 25.0	0.91 – 1.70	1.19 – 1.44
3.8		25.1 – 30.0		1.45 – 1.70
4.0 Poor		30.1 – 34.0		1.71 – 1.97
4.2		34.1 – 38.0		1.98 – 2.23
4.4	30.1 – 50.0	38.1 – 42.0	1.71 – 3.0	2.24 – 2.49
4.6		42.1 – 46.0		2.50 – 2.74
4.8		46.1 – 50.0		2.76 – 3.0
5.0 Fail		50.1 – 60.0		3.01 – 30.0
5.2		60.1 – 70.0		30.1 – 60.0
5.4	> 50.0	70.1 – 80.0	>3.0	60.1 – 90.0
5.6		80.1 – 90.0		90.1 – 110.0
5.8		>90.0		>110.0

SM 4 Score system for service condition [21]

No.	Code	Description	Condition rating score		
			S	M	L
1	DE	Debris silty	8	20	40
2	DG	Debris greasy	8	20	40
3	ED	Encrustation deposit	0	5	20
4	OT	Obstruction Temporary	0	5	20
5	RI	Root Intrusion	5	25	70

SM 5 Grading systems for service condition [21]

Grading	Peak score		Mean score	
	Initial	**Intermediate**	**Initial**	**Intermediate**
1.0 Excellent	0 – 3.0	0 – 3.0	0 – 0.50	0 – 0.50
2.0 Good	3.1 – 7.0	3.1 – 7.0	0.51 – 1.0	0.51 – 1.0
3.0 Moderate		7.1 – 10.3		1.10 – 1.40
3.4	7.1 – 15.0	10.4 – 13.5	1.1 – 2.0	1.41 – 1.80
3.8		13.6 – 15.0		1.81 – 2.00
4.0 Poor		15.1 – 18.0		2.10 – 2.60
4.2		18.1 – 21.0		2.61 – 3.20
4.4	15.1 – 30.0	21.1 – 24.0	2.1 – 5.00	3.21 – 3.80
4.6		24.1 – 27.0		3.81 – 4.40
4.8		27.1 – 30.0		4.41 – 5.0
5.0 Fail		30.1 – 40.0		5.01 – 5.60
5.2		40.1 – 50.0		5.61 – 6.20
5.4	>30.0	50.1 – 60.0	>5.00	6.21 – 6.80
5.6		60.1 – 70.0		6.81 – 7.40
5.8		>70.0		>7.40

SM 6 Robot with CCTV used for data collection by UBA.

SM 7 Example photos of sewer pipe condition for each defect and its score in Dindaeng District

Defect Code	Small (Score Type)	Medium (Score Type)	Large (Score Type)
CC	 Score - 2	–	–
CL	 Score - 2	 Score - 15	 Score - 30
IP	 Score - 2	 Score - 15	 Score - 30
JF	 Score - 1	 Score - 10	 Score - 25
SD	 Score - 3	 Score - 20	 Score - 60

SM 7 Example photos of sewer pipe condition for each defect and its score in Dindaeng District (*continued*)

Defect Code	Small (Score Type)	Medium (Score Type)	Large (Score Type)
OT	 Score - 8	 Score - 20	–
DE	 Score - 8	–	–
DG	 Score - 8	–	–